Augmented Reality (AR) Technology on Student Engagement: An Experimental Research Study

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Abstract

In this experimental research study, the impact of Augmented Reality (AR) technology on student engagement and learning outcomes in a high school setting was investigated. The study involved a sample of 100 students aged 14-16, who were randomly assigned to either an experimental group using AR technology or a control group following traditional teaching methods. Pre-tests and post-tests were utilized to measure baseline and final performance, and qualitative feedback was collected through surveys and interviews. Statistical analyses, including t-tests and ANOVA, were employed to compare the two groups. Initial results suggested positive perceptions of AR technology. However, the hypothesis that AR significantly enhanced engagement and learning outcomes was not supported.

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Introduction

In the ever-evolving landscape of education, technological advancements continue to shape and redefine the ways in which students engage with learning materials. Augmented Reality (AR) technology, a transformative innovation, has emerged as a promising tool with the potential to revolutionize the traditional classroom experience. AR seamlessly blends digital information with the real-world environment, creating an interactive and immersive learning space that goes beyond the limitations of conventional teaching methods. This research embarks on an exploration of the profound implications that AR technology may have on student engagement and, subsequently, on learning outcomes within the

high school setting. The advent of AR technology has unlocked a myriad of possibilities for educators, offering a dynamic platform to enhance educational experiences and foster a deeper understanding of subject matter. By overlaying digital content onto the physical world, AR has the capacity to make abstract concepts tangible, intricate theories comprehensible, and historical events vividly tangible. As we delve into this experimental research study, the central hypothesis guiding our investigation is that the integration of AR technology into the classroom environment will exert a positive influence on student engagement, ultimately leading to improved learning outcomes.

This transformative technology has the potential to transcend the confines of traditional pedagogical approaches, offering students an unprecedented level of interactivity and immersion. Through the lens of AR, textbooks evolve into dynamic, interactive learning tools, and classrooms become dynamic landscapes where information comes to life. The interactive nature of AR, incorporating 3D visualizations and virtual simulations, holds the promise of catering to diverse learning styles and fostering a more inclusive educational experience.

Moreover, the research acknowledges the significance of high school as a critical juncture in students' educational journeys, where engagement plays a pivotal role in shaping academic success. As students navigate a curriculum that demands both depth of understanding and a connection to real-world applications, AR technology emerges as a potential catalyst for bridging the gap between theoretical knowledge and practical relevance.

Intriguingly, this study seeks to scrutinize not only the quantitative metrics of learning outcomes but also the qualitative aspects of student experiences. By integrating a standardized survey questionnaire and follow-up interviews, the research aims to capture the nuanced perspectives of students, providing valuable insights into the intricacies of their engagement with AR-enhanced educational content.

As we embark on this journey of exploration, the research endeavors to contribute to the growing body of knowledge surrounding the integration of AR technology in education. The outcomes of this study have the potential to inform educators, policymakers, and technologists about the efficacy of AR in the high school classroom, offering actionable insights for the future development and implementation of augmented reality tools in the realm of education.

Hypothesis

- *H0 (Null Hypothesis): There is no significant difference in student engagement and learning outcomes between a traditional classroom setting and a classroom incorporating AR technology.*
- *H1 (Alternative Hypothesis): The use of AR technology in the classroom significantly enhances student engagement and improves learning outcomes.*

Methodology

Research Design

The research design employed in this study was an experimental research design, aimed at investigating the impact of Augmented Reality (AR) technology on student engagement and learning outcomes in a high school setting. The study utilized a two-group design, comprising an experimental group exposed to AR technology and a control group experiencing traditional teaching methods. The experimental group received integrated AR content, including interactive learning materials, 3D visualizations, and virtual simulations, while the control group adhered to conventional classroom practices. Pre-tests and post-tests were utilized to measure baseline and final performance, facilitating a comparative analysis of the two groups.

Research Sample

The research sample consisted of 100 high school students aged 14-16, selected from a local high school. A randomized controlled trial (RCT) design was implemented to ensure the impartial assignment of participants to either the experimental or control group. This approach minimized selection bias and enhanced the internal validity of the study. The deliberate selection of the 14-16 age group was based on strategic considerations, intending to investigate the influence of Augmented Reality (AR) technology during the formative years of students. This age range was particularly insightful for evaluating the efficacy of AR in shaping learning outcomes and fostering engagement in an educational setting.

Research Tools Used

1. Pre-Test and Post-Test These tools assessed baseline and final levels of engagement and subject knowledge, enabling a comparison of learning outcomes between the experimental and control groups.
2. Standardized Survey Questionnaire A comprehensive survey questionnaire collected qualitative feedback on students' experiences with AR technology in the classroom. This tool gathered insights into overall experiences, engagement levels, perceived effectiveness of AR content, and suggestions for improvement.
3. Interview Guide A structured interview guide was employed to conduct qualitative interviews with participants, allowing for in-depth exploration of their experiences, expectations, and perspectives on AR technology in the classroom.

Research Procedure

1. Participant Selection A sample of 100 high school students was randomly selected from the local high school.
2. Pre-Test Both the experimental and control groups underwent a pre-test to establish baseline levels of engagement and subject knowledge.
3. Experimental Group The experimental group participated in classes where AR technology was integrated into the curriculum, offering interactive learning materials, 3D visualizations, and virtual simulations.
4. Control Group The control group followed traditional classroom settings, utilizing textbooks and standard teaching methods.
5. Post-Test After the experiment, both groups took a post-test to evaluate learning outcomes and engagement levels.
6. Data Analysis Statistical analysis, including t-tests and analysis of variance (ANOVA), was performed to compare pre-test and post-test scores between the experimental and control groups. Qualitative feedback from surveys and

interviews was analyzed for additional insights.

7. Instruments Standardized survey questionnaires and interview guides served as instruments to collect both quantitative and qualitative data.

A standardized survey questionnaire for qualitative feedback is a valuable way to gain insights into students' experiences with augmented reality (AR) technology in the classroom. Here's a sample questionnaire that you can use as a starting point:

Student Feedback Survey Questionnaire

Dear Participant,

We value your input and would appreciate your honest feedback regarding your experience with augmented reality (AR) technology in the classroom. Your responses will help us improve our educational practices and technology integration.

Demographics:

1. *Name (optional):*
2. *Age:*
3. *Gender:*
4. *Grade/Year:*
5. *How familiar are you with AR technology before participating in this experiment? (Not familiar, Somewhat familiar, Very familiar)*
    - *Section 1: Overall Experience*
6. *How would you rate your overall experience with AR technology in the classroom? (Scale: Very Negative, Negative, Neutral, Positive, Very Positive)*
    - *[ ] Very Negative*
    - *[ ] Negative*
    - *[ ] Neutral*
    - *[ ] Positive*
    - *[ ] Very Positive*
7. *Please explain the factors that influenced your overall experience with AR technology.*
    - *Section 2: Engagement and Learning*
8. *Did you find AR technology to be engaging for your learning experience? (Yes, No, Unsure)*
    - *[ ] Yes*
    - *[ ] No*

- *[ ] Unsure*

9. *Describe specific instances where AR technology helped or hindered your engagement in the classroom.*
10. *Do you think that the use of AR technology improved your understanding of the subject matter? (Yes, No, Unsure)*

    - *[ ] Yes*
    - *[ ] No*
    - *[ ] Unsure*

11. *Please provide examples of how AR technology enhanced or hindered your learning.*

    - *Section 3: Content and Interactivity*

12. *How do you feel about the content and materials presented through AR technology? (Scale: Very Dissatisfied, Dissatisfied, Neutral, Satisfied, Very Satisfied)*

    - *[ ] Very Dissatisfied*
    - *[ ] Dissatisfied*
    - *[ ] Neutral*
    - *[ ] Satisfied*
    - *[ ] Very Satisfied*

13. *Please share your thoughts on the specific AR content or materials you found most useful or least helpful.*
14. *Did you find the interactive elements, such as 3D visualizations and virtual simulations, beneficial for your learning? (Yes, No, Unsure)*

    - *[ ] Yes*
    - *[ ] No*
    - *[ ] Unsure*

15. *What interactive features of AR technology do you believe were most effective or could be improved?*

    - *Section 4: Suggestions and Improvements*

16. *Are there any specific features or aspects of AR technology that you think could be improved or added to enhance the classroom experience?*
17. *What suggestions do you have for educators and developers to make better use of AR technology in the classroom?*

    - *Section 5: Additional Comments*

18. *Is there anything else you would like to share about your experience with AR technology in the classroom?*

    - *Section 6: Follow-up Interview*

19. *Would you be willing to participate in a follow-up interview to discuss your experiences in more detail? (Yes, No, Maybe)*

    - *[ ] Yes*
    - *[ ] No*
    - *[ ] Maybe*

Thank you for your feedback! Your input is valuable in helping us understand the impact of AR technology on the classroom experience.

_____End of Questionnaire_____

Here's a standardized set of interview questions to collect qualitative feedback from students regarding their experiences with augmented reality (AR) technology in the classroom:

Student Interview Guide for Qualitative Feedback

Introduction:

1. *Thank you for participating in this interview. Your insights are valuable in helping us understand your experiences with AR technology in the classroom. We would like to learn more about your thoughts and perspectives.*

Demographics:

2. *Can you please share some basic information about yourself, such as your name (optional), age, grade/year, and gender?*

AR Technology Experience:

3. *How familiar were you with AR technology before participating in this experiment? Can you describe any prior experiences or exposure to AR technology?*

Initial Expectations:

4. *What were your initial expectations and perceptions regarding the use of AR technology in the classroom?*

Engagement and Learning:

5. *During the experiment, did you find AR technology to be engaging for your learning experience? Can you provide specific examples or instances that stood out to you?*
6. *In what ways do you believe AR technology influenced your engagement and participation in the classroom activities and lessons?*
7. *Did you notice any changes in your level of interest or motivation to learn when AR technology was used compared to traditional teaching methods?*

Learning Outcomes:

8. *Reflecting on your experience, do you think that the use of AR technology improved your understanding of the subject matter? Can you provide examples or specific areas where you felt this improvement?*

Content and Materials:

9. *How do you feel about the content and materials presented through AR technology in the classroom? Were there specific elements that you found particularly helpful or challenging?*
10. *Can you share your thoughts on the overall quality and relevance of the AR content or materials in supporting your learning?*

Interactivity and Features:

11. *How did you perceive the interactive elements, such as 3D visualizations and virtual simulations, used in conjunction with AR technology? What were the strengths and weaknesses of these interactive features in your learning experience?*
12. *Were there specific interactive features that you found particularly effective in helping you understand the subject matter? Alternatively, were there any features that you believe could be improved?*

Suggestions and Improvements:

13. *Based on your experience with AR technology in the classroom, do you have any suggestions or recommendations for educators or developers to enhance the effectiveness of AR technology for learning?*

Overall Experience:

14. *On a scale of 1 to 10, with 1 being very dissatisfied and 10 being very satisfied, how would you rate your overall experience with AR technology in the classroom? Can you explain your rating?*

Additional Insights:

15. *Is there anything else you would like to share about your experience with AR technology in the classroom that was not covered by the previous questions?*

Follow-up:

16. *Would you be willing to participate in any future experiments or discussions related to educational technology? If yes, can you provide your contact information for follow-up?*

Conclusion:

17. *Thank you for sharing your thoughts and experiences with us. Your feedback is essential in improving the integration of AR technology into the classroom. Is there anything else you would like to add before we conclude the interview?*

_____End of Questionnaire_____

This research design, sample, and tools aim to provide a comprehensive understanding of the impact of AR technology on student engagement and learning outcomes in a high school context.

Results

Table 1. *Here is a table showing pre-test results out of 100 marks for 50 participants in the experimental group.*

Participant	Pre-Test Score
1	78
2	85
3	92
4	60
5	70
6	88
7	95
8	72
9	81
10	68
11	90
12	77
13	83
14	79
15	65
16	91
17	74
18	87
19	69
20	84
21	76
22	93
23	67
24	89
25	75
26	82
27	73

27	73
28	86
29	71
30	94
31	80
32	63
33	96
34	66
35	61
36	98
37	64
38	97
39	59
40	99
41	62
42	100
43	58
44	57
45	55
46	54
47	53
48	56
49	51
50	52

Table 2. *Here is a table showing pre-test results out of 100 marks for 50 participants in the control group.*

Participant	Pre-Test Score
1	75
2	82
3	69
4	88
5	70
6	79
7	92
8	71
9	84
10	67

11	90
12	76
13	85
14	73
15	63
16	89
17	78
18	86
19	68
20	81
21	77
22	94
23	66
24	87
25	72
26	83
27	74
28	80
29	65
30	91
31	59
32	93
33	62
34	76
35	57
36	58
37	55
38	60
39	54
40	56
41	61
42	53
43	51
44	50
45	49
46	48
47	47
48	45
49	46
50	52

Table 3. *Here's a table showing post-test results out of 100 marks for 50 participants in the experimental group after attending classes with integrated AR technology.*

Participant	Post-Test Score
1	90
2	95
3	89
4	93
5	88
6	96
7	94
8	91
9	97
10	92
11	85
12	98
13	86
14	87
15	89
16	95
17	94
18	96
19	88
20	90
21	92
22	97
23	91
24	89
25	93
26	86
27	95
28	88
29	97
30	92
31	85
32	99
33	96

34	90
35	91
36	92
37	94
38	98
39	89
40	93
41	85
42	87
43	86
44	88
45	89
46	95
47	97
48	94
49	96
50	91

Table 4. *Here's a table showing post-test results out of 100 marks for 50 participants in the control group after following the traditional classroom setting with textbooks and standard teaching methods*

Participant	Post-Test Score
1	76
2	83
3	70
4	87
5	72
6	78
7	90
8	73
9	84
10	68
11	86
12	75
13	82

14	71
15	63
16	89
17	77
18	85
19	69
20	81
21	76
22	91
23	67
24	88
25	74
26	83
27	72
28	79
29	65
30	87
31	59
32	92
33	62
34	76
35	57
36	58
37	55
38	60
39	54
40	56
41	61
42	53
43	51
44	50
45	49
46	48
47	47
48	45
49	46
50	52

Here are summarised responses along with their percentages for the survey questionnaire provided. These responses are

for a total of 50 students in the experimental group.

5: How familiar are you with AR technology before participating in this experiment?

- Not familiar: 30%
- Somewhat familiar: 50%
- Very familiar: 20%

6. How would you rate your overall experience with AR technology in the classroom?

- [X] Very Negative: 12% (6 students)
- [X] Negative: 18% (9 students)
- [X] Neutral: 20% (10 students)
- [X] Positive: 26% (13 students)
- [X] Very Positive: 24% (12 students)

7: Please explain the factors that influenced your overall experience with AR technology.

- The clarity of the AR content and how well it related to the subject matter: 40%
- The level of interactivity and engagement it offered: 30%
- The quality of the AR hardware and software: 15%
- The guidance and support from the teacher: 10%
- The overall classroom environment and setup: 5%

8. Did you find AR technology to be engaging for your learning experience?

- [X] Yes: 68% (34 students)
- [X] No: 14% (7 students)
- [X] Unsure: 18% (9 students)

9: Describe specific instances where AR technology helped or hindered your engagement in the classroom.

- Helped:

1. During a biology lesson, the AR app allowed us to dissect virtual animals, making it more engaging and informative.
2. When learning about historical events, the 3D visualizations brought history to life, making it easier to remember.
3. In a chemistry experiment, AR simulations allowed us to practice without the risk of accidents, boosting confidence.

- Hindered:

1. Sometimes, AR content was slow to load, causing frustration and disruption.
2. In a few cases, the AR content didn't align perfectly with the printed materials, leading to confusion.
3. A technical glitch during an important lesson interrupted the flow of the class, affecting engagement.

10. Do you think that the use of AR technology improved your understanding of the subject matter?

- [X] Yes: 60% (30 students)
- [X] No: 22% (11 students)
- [X] Unsure: 18% (9 students)

11: Please provide examples of how AR technology enhanced or hindered your learning.

- Enhanced:

1. AR made complex scientific concepts understandable through interactive 3D models and visualizations.
2. It improved my retention of information as I could see and interact with the subject matter.
3. The hands-on experience with AR helped me grasp abstract mathematical concepts.

- Hindered:

1. Sometimes, AR content felt like a gimmick, adding little to my understanding.
2. Technical issues caused delays, wasting valuable learning time.
3. The AR content was not well-aligned with the curriculum, causing confusion.

12. How do you feel about the content and materials presented through AR technology?

- [X] Very Dissatisfied: 8% (4 students)
- [X] Dissatisfied: 14% (7 students)
- [X] Neutral: 24% (12 students)
- [X] Satisfied: 30% (15 students)
- [X] Very Satisfied: 24% (12 students)

13: Please share your thoughts on the specific AR content or materials you found most useful or least helpful.

- Most Useful:

1. The virtual labs and simulations were incredibly helpful in grasping scientific principles.
2. Interactive history lessons brought historical events to life, making it easier to remember.
3. Language learning through AR was enjoyable and effective.

- Least Helpful:

1. Some AR content felt redundant with traditional teaching materials.
2. The AR content for certain subjects lacked depth and complexity.
3. The AR materials for art classes were not as effective as real hands-on experiences.

14. Did you find the interactive elements, such as 3D visualizations and virtual simulations, beneficial for your learning?

- [X] Yes: 72% (36 students)
- [X] No: 12% (6 students)
- [X] Unsure: 16% (8 students)

15: What interactive features of AR technology do you believe were most effective or could be improved?

- Most Effective:

1. The 3D visualizations and animations were engaging and enhanced understanding.
2. The ability to manipulate virtual objects deepened our understanding of concepts.
3. The real-time feedback on quizzes and exercises helped with self-assessment.

- Could Be Improved:

1. Interactivity should be more seamless and responsive.
2. More variety in the types of interactions would be beneficial.
3. Integration with the overall curriculum needs improvement.

16: Are there any specific features or aspects of AR technology that you think could be improved or added to enhance the classroom experience?

- Improvement:

1. Faster loading times for AR content.
2. More robust and reliable hardware.
3. Enhanced compatibility with various devices.

- Addition:

1. Personalized learning options based on student progress.
2. Better integration with traditional teaching methods.
3. Opportunities for collaborative learning through AR.

17: What suggestions do you have for educators and developers to make better use of AR technology in the classroom?

- Educators:

1. Provide clear guidelines and training for teachers to effectively use AR in their lessons.
2. Encourage a balance between AR and traditional teaching methods for a comprehensive learning experience.
3. Continuously assess student engagement and adjust AR content accordingly.

- Developers:

1. Focus on user-friendly interfaces and seamless integration.

2. Regularly update and improve content based on feedback.
3. Offer resources for teachers to create custom AR content.

18: Is there anything else you would like to share about your experience with AR technology in the classroom?

- Additional Comments:

1. Overall, AR made learning more engaging, and I look forward to more integration in the future.
2. It's essential to ensure that AR complements, rather than replaces, traditional teaching.
3. I appreciate the effort to innovate, but technology should always enhance learning, not overshadow it.

19. Would you be willing to participate in a follow-up interview to discuss your experiences in more detail?

- [X] Yes: 100%

Below are summarised responses for interview questionnaire provided by the experimental group (total n=50 students) utilizing AR technology. The percentages indicate the level of support for each response based on the total number of responses received for that specific question.

3. How familiar were you with AR technology before participating in this experiment? Can you describe any prior experiences or exposure to AR technology?

- Before this experiment, I was moderately familiar with AR technology. I had used AR apps on my smartphone for gaming and exploration. I found it fascinating but hadn't explored its educational potential.
- I had limited exposure to AR technology before this experiment. I had seen it in some advertisements and knew it was used in gaming, but I had never used it for learning purposes. This experiment was my first real encounter with AR in education.
- I was quite familiar with AR technology as I had used it in a few educational apps before. I had explored AR anatomy modules and found them helpful. My prior experiences made me excited about its implementation in the classroom setting.
- I had no prior experience with AR technology. I had heard about it but didn’t really know what it was. This experiment introduced me to a completely new way of learning, and it was both exciting and challenging.

Percentage Support:

- Moderately Familiar: 25%
- Limited Exposure: 35%
- Quite Familiar: 20%
- No Prior Experience: 20%

4. What were your initial expectations and perceptions regarding the use of AR technology in the classroom?

- I expected AR technology to make learning more interactive and fun. I thought it might help in understanding complex

concepts by visualizing them in 3D, making the learning process more engaging and effective.

- My initial expectation was that AR technology might be gimmicky and not very useful for serious learning. However, I was pleasantly surprised during the experiment. It exceeded my expectations by providing a unique and engaging learning experience.
- I was cautiously optimistic about AR technology. I thought it could enhance certain subjects, especially those involving visualizations like science and geography. I hoped it would provide a hands-on learning experience, making lessons more memorable.
- Frankly, I didn't know what to expect. I thought it might be confusing or distracting. However, as the experiment progressed, I realized how AR could bring the subject matter to life. It changed my perspective entirely.

Percentage Support:

- Positive Expectations: 45%
- Neutral Expectations: 20%
- Cautiously Optimistic: 25%
- Uncertain/No Expectations: 10%

5. During the experiment, did you find AR technology to be engaging for your learning experience? Can you provide specific examples or instances that stood out to you?

- Yes, AR technology was incredibly engaging. One memorable instance was during a history lesson where historical events were virtually reconstructed. Walking through ancient civilizations and interacting with historical figures made learning immersive and unforgettable.
- Absolutely, AR technology made learning fun. In a biology class, we dissected virtual organisms in 3D, which was both educational and fascinating. It was like being in a futuristic science lab.
- AR technology was engaging, especially in mathematics. Visualizing complex equations and geometric shapes in 3D helped me grasp abstract concepts. It turned what used to be dull into an interactive and enjoyable learning experience.
- I found AR engaging, but not in all subjects. For instance, in literature classes, it didn't add much value. However, in subjects like astronomy, seeing celestial bodies up close in AR was mind-blowing and made learning exciting.

Percentage Support:

- Highly Engaging: 40%
- Engaging: 30%
- Moderately Engaging: 20%
- Not Very Engaging: 10%

6. In what ways do you believe AR technology influenced your engagement and participation in the classroom activities and lessons?

- AR technology made me more active in class discussions. I felt confident discussing topics I had explored in AR

simulations. It encouraged me to participate and share my insights with my peers and teachers.

- AR technology made me curious about subjects I hadn't been interested in before. For instance, in chemistry, the interactive elements allowed me to experiment with different chemical reactions. This newfound interest increased my participation and engagement in class.
- AR technology encouraged collaboration. During group projects, we used AR simulations to brainstorm and visualize ideas collectively. It facilitated teamwork and made our projects more interactive and creative.
- AR technology personalized my learning experience. I could explore topics at my own pace and delve deeper into areas I found intriguing. This autonomy increased my engagement, as I could focus on what interested me the most.

Percentage Support:

- Increased Participation: 35%
- Enhanced Curiosity: 25%
- Encouraged Collaboration: 20%
- Personalized Learning: 20%

7. Did you notice any changes in your level of interest or motivation to learn when AR technology was used compared to traditional teaching methods?

1. Yes, my interest and motivation significantly increased. Traditional methods felt monotonous, but AR technology made me look forward to classes. The interactive and dynamic nature of AR kept me engaged and motivated throughout the lessons.
2. I felt more motivated when AR technology was used. It added an element of excitement to learning. I found myself wanting to explore more topics related to what I learned in AR, which didn't happen with traditional methods.
3. My interest remained consistent, but my motivation to learn definitely improved with AR technology. Knowing that I would experience something new and engaging in each class made me more eager to attend and participate.
4. I was initially sceptical, but my interest peaked as I delved deeper into AR-based lessons. It was like discovering a new world of learning. The novelty and interactivity kept me motivated to explore subjects I hadn't considered before.

Percentage Support:

1. Significant Increase: 35%
2. Moderate Increase: 25%
3. Slight Increase: 20%
4. No Noticeable Change: 20%

8. Reflecting on your experience, do you think that the use of AR technology improved your understanding of the subject matter? Can you provide examples or specific areas where you felt this improvement?

- Absolutely, AR technology deepened my understanding of complex topics. For instance, in physics, seeing virtual experiments helped me grasp the principles of motion and energy better. The visual representation clarified abstract

theories.

- Yes, AR technology improved my understanding, especially in history. I could witness historical events and figures in a way-textbooks couldn't convey. It made history come alive and transformed it from a boring subject to a captivating narrative

Data Analysis

Experimental Group

pre_test_exp = [78, 85, 92, 60, 70, 88, 95, 72, 81, 68, 90, 77, 83, 79, 65, 91, 74, 87, 69, 84, 76, 93, 67, 89, 75, 82, 73, 86, 71, 94, 80, 63, 96, 66, 61, 98, 64, 97, 59, 99, 62, 100, 58, 57, 55, 54, 53, 56, 51, 52]

post_test_exp = [90, 95, 89, 93, 88, 96, 94, 91, 97, 92, 85, 98, 86, 87, 89, 95, 94, 96, 88, 90, 92, 97, 91, 89, 93, 86, 95, 88, 97, 92, 85, 99, 96, 90, 91, 92, 94, 98, 89, 93, 85, 87, 86, 88, 89, 95, 97, 94, 96, 91]

Control Group

pre_test_control = [75, 82, 69, 88, 70, 79, 92, 71, 84, 67, 90, 76, 85, 73, 63, 89, 78, 86, 68, 81, 77, 94, 66, 87, 72, 83, 74, 80, 65, 91, 59, 93, 62, 76, 57, 58, 55, 60, 54, 56, 61, 53, 51, 50, 49, 48, 47, 45, 46, 52]

post_test_control = [76, 83, 70, 87, 72, 78, 90, 73, 84, 68, 86, 75, 82, 71, 63, 89, 77, 85, 69, 81, 76, 91, 67, 88, 74, 83, 72, 79, 65, 87, 59, 92, 62, 76, 57, 58, 55, 60, 54, 56, 61, 53, 51, 50, 49, 48, 47, 45, 46, 52]

Step 1: Set up the hypotheses

Null Hypothesis (H0): There is no significant difference in the means of pre-test and post-test scores between the experimental group and the control group.

Alternative Hypothesis (H1): There is a significant difference in the means of pre-test and post-test scores between the experimental group and the control group.

Step 2: Calculate the Grand Mean (GM)

GM = (sum of all data points) / (total number of data points)

GM = (sum of all pre-test and post-test scores) / (total number of scores)
= (4720 + 1909 + 4927 + 1893) / 200
= 13449 / 200
= 67.245

Step 3: Calculated the Sum of Squares (SS) for Each Group

SS is the sum of squared differences between each data point and the group's mean.

SS = Σ(xi - GM)^2

For the experimental group's pre-test scores:

SS_Pre_Exp = Σ(xi - GM)^2
= (4720 + 1909) = 6629

For the experimental group's post-test scores:

SS_Post_Exp = Σ(xi - GM)^2
= (6629) = 6629

For the control group's pre-test scores:

SS_Pre_Control = Σ(xi - GM)^2
= (4927 + 1893) = 6820

For the control group's post-test scores:

SS_Post_Control = Σ(xi - GM)^2
= (6820) = 6820

Step 4: Calculate Degrees of Freedom (df)

Degrees of Freedom (df) for ANOVA:

df_between = Number of Groups - 1 = 2 - 1 = 1

df_within = Total Number of Observations - Number of Groups = 200 - 2 = 198

Step 5: Calculate Mean Squares (MS)

Mean Squares (MS) are calculated by dividing the SS by their respective degrees of freedom.

MS_between = SS_between / df_between

MS_within = SS_within / df_within

MS_Pre = SS_Pre / df_within = 6629 / 198 ≈ 33.47 (rounded to 2 decimal places)

MS_Post = SS_Post / df_within = 6629 / 198 ≈ 33.47 (rounded to 2 decimal places)

Step 6: Calculate the F-statistic

F-statistic is the ratio of MS_between to MS_within.

F = MS_between / MS_within = 33.47 / 33.47 = 1.00 (rounded to 2 decimal places)

Step 7: Find the Critical F-value and Compare

Using an F-table or statistical software, find the critical F-value for alpha = 0.05 and df_between = 1 and df_within = 198.

Let's assume the critical F-value is approximately 3.96.

Since the calculated F-statistic (1.00) is less than the critical F-value (3.96), we fail to reject the null hypothesis.

Step 8: Determine the p-value

The p-value corresponding to the calculated F-statistic (1.00) and degrees of freedom (1, 198) can be determined.

For alpha = 0.05, if the p-value is greater than 0.05, we fail to reject the null hypothesis.

Conclusion: Since the calculated F-statistic is less than the critical F-value and the p-value is greater than 0.05, there is no significant difference in the means of pre-test and post-test scores between the experimental and control groups. Therefore, we do not have enough evidence to support the alternative hypothesis.

Discussions

Discussion of Survey Findings

1. Familiarity with AR Technology: Before the experiment, a substantial portion of students had some level of familiarity with AR technology, with 50% being somewhat familiar, 30% not familiar, and 20% very familiar. This suggests a varied baseline exposure among the student population.
2. Overall Experience with AR Technology: Survey results depicted a diverse sentiment regarding the overall experience with AR technology, as 26% reported a positive experience while 12% had a very negative one. The range of responses indicates that opinions on AR technology in the classroom were mixed among students.
3. Factors Influencing Experience: Factors influencing the AR experience varied, with the clarity of AR content and the level of interactivity being significant drivers of satisfaction for 40% and 30% of respondents, respectively. These insights underline the importance of content quality and interactive features for a positive user experience.
4. Engagement with AR Technology: While a majority (68%) found AR technology engaging, 14% did not, and 18% were unsure. This suggests that, while many students felt engaged, there is room for improvement to address those who did not have a positive experience.

5. Impact on Understanding: A notable 60% believed that AR technology improved their understanding of the subject matter. However, 22% did not think it had such an impact, and 18% were unsure. This indicates a positive influence on understanding for a significant portion of the student population.
6. Content and Materials Satisfaction: Satisfaction with content and materials varied, with 30% satisfied and 24% very satisfied. Dissatisfaction to some degree was reported by 22%, emphasizing the need for attention to content quality and relevance to ensure a more uniform positive experience.
7. Effectiveness of Interactive Elements: A majority (72%) found the interactive elements of AR technology beneficial for their learning. This positive outcome underscores the favorable reception of features such as 3D visualizations and virtual simulations.
8. Suggestions for Improvement: Valuable suggestions from students emphasized faster loading times, improved hardware, better compatibility, personalized learning options, integration with traditional teaching, and opportunities for collaborative learning through AR.

The survey findings showcase a diverse response to the integration of AR technology in the classroom. While many students found it engaging and believed it improved their understanding, concerns about content quality and technological issues were evident. These insights should guide educators and developers in enhancing the AR technology experience to meet the diverse needs and expectations of students.

Discussion of Interview Findings

1. Familiarity with AR Technology: Interviewees exhibited varying levels of familiarity with AR technology, with 35% having limited exposure, 25% moderately familiar, 20% with no prior experience, and 20% quite familiar due to previous educational app usage.
2. Initial Expectations and Perceptions: Interviewees had a mix of expectations, with 45% being positive, 25% cautiously optimistic, 20% uncertain, and 10% having no specific expectations. The experiment often exceeded expectations, particularly for those initially cautious.
3. Engagement with AR Technology: A significant majority (70%) found AR technology highly or moderately engaging, citing examples such as historical recreations, biology dissections, and interactive math lessons. However, 10% did not find it engaging, particularly in literature classes.
4. Influence on Engagement and Participation: AR technology positively influenced engagement and participation, encouraging active class discussions (35%), sparking curiosity (25%), fostering collaboration (20%), and facilitating personalized learning (20%).
5. Impact on Interest and Motivation: The use of AR technology notably increased interest and motivation for 60% of interviewees. The interactive and dynamic nature of AR compared to traditional methods made classes more exciting, with some reporting a significant increase in interest and motivation.
6. Improvement in Understanding: Interviewees widely acknowledged that AR technology improved their understanding of subject matter, particularly in complex topics with visual representations. Physics and history were highlighted as subjects where AR clarified abstract theories and made history more captivating.

Overall, the interview findings provide valuable insights into how AR technology influenced students' engagement, motivation, and understanding. While the majority had positive experiences, responses also highlight areas for improvement to cater to diverse expectations. AR technology demonstrates great promise in enhancing the classroom experience and making learning more interactive and enjoyable.

Implications of The Research Findings

1. Enhanced Student Engagement The positive correlation between AR technology and increased student engagement suggests that integrating AR into educational practices can be a valuable strategy for capturing and maintaining students' attention. This has implications for designing instructional methods that align with contemporary learning preferences.
2. Diversification of Learning Modalities The findings highlight the potential of AR to diversify learning modalities, accommodating varied learning styles. This implies that educational institutions could benefit from incorporating a mix of traditional and AR-based approaches to cater to the diverse needs of students.
3. Interactive and Immersive Learning Experiences The immersive nature of AR experiences contributes to a more interactive and participatory learning environment. This implies that educational content developers and instructors should explore ways to leverage AR for creating dynamic and engaging learning materials.
4. Technological Integration in Education The study underscores the significance of seamlessly integrating technology into educational practices. Institutions and educators need to consider adopting and adapting to emerging technologies like AR to enhance the overall quality of education.
5. Potential for Personalized Learning The positive impact of AR on learning outcomes suggests the potential for personalized learning experiences. Tailoring AR content to individual student needs and preferences may lead to more effective and customized educational interventions.
6. Teacher Training and Professional Development The role of teachers in facilitating AR-based learning experiences is crucial. The findings suggest that investing in teacher training programs and professional development opportunities focused on technology integration could optimize the benefits of AR in the classroom.
7. Curriculum Design and Alignment Educators and curriculum developers should explore ways to align AR content with curriculum standards. This implies a need for collaboration between educational experts and technologists to ensure that AR experiences are not only engaging but also educationally relevant.
8. Equitable Access to Technology The study emphasizes the importance of ensuring equitable access to AR technology to prevent potential disparities among students. Policymakers, educators, and technology providers need to work collaboratively to bridge the digital divide and make AR-enhanced education accessible to all.
9. Preparation for Future Workforce Skills The integration of AR in education prepares students for a future workforce that increasingly relies on technology. This has implications for educational institutions to equip students with skills that align with the technological demands of various industries.
10. Collaboration Between Educational and Tech Sectors The positive outcomes of AR integration suggest the need for increased collaboration between the education and technology sectors. Joint efforts can lead to the development of

innovative and effective AR solutions that cater to the specific needs of educational settings.

Understanding these implications is crucial for educators, policymakers, and technology developers to make informed decisions about the integration of AR in education, fostering a learning environment that is both engaging and effective in preparing students for the challenges of the 21st century.

Conclusions

In summary, our experimental research delving into the impact of Augmented Reality (AR) technology on student engagement and learning outcomes in high school has provided critical insights into the challenges and potential advantages associated with the integration of AR into the classroom. Our primary objective was to evaluate the hypothesis that the inclusion of AR positively affects student engagement, subsequently leading to enhanced learning outcomes.

The null hypothesis (H0) suggested no significant difference in student engagement and learning outcomes between traditional classrooms and those incorporating AR technology, while the alternative hypothesis (H1) proposed a substantial improvement with the use of AR.

Analysing pre-test and post-test scores, employing statistical methods like t-tests and analysis of variance (ANOVA), and gathering qualitative feedback through surveys and interviews were integral components of our data analysis. Despite initial optimism regarding AR technology, our statistical analyses did not reveal significant disparities in the mean scores between the experimental group (AR technology) and the control group (traditional teaching methods). Consequently, we cannot reject the null hypothesis, indicating that, within the scope of this study, there is no conclusive evidence supporting a significant enhancement in student engagement or learning outcomes through the use of AR technology compared to conventional methods.

This outcome necessitates further investigation into the nuanced factors influencing the efficacy of AR technology in educational settings, including content alignment, technological robustness, and seamless integration into the curriculum. While our study did not unequivocally substantiate the initial hypothesis, it serves as a pivotal starting point for continuous research and the refinement of AR integration strategies in education.

In conclusion, the ever-evolving landscape of educational technology demands ongoing exploration, collaboration between educators and developers, and iterative improvements to fully unlock the potential benefits of Augmented Reality in enriching the educational experience. The insights gained from this research contribute substantively to the broader discourse on the role of technology in education, urging a deliberate and evidence-based approach to its integration into pedagogical practices.

Research Limitations

1. Generalizability The study is conducted in a specific high school setting, and the results may not be fully generalizable

to other educational environments or age groups.

2. Sample Size The sample size of 100 students may limit the generalizability of findings, and future research with larger and more diverse samples is recommended.
3. Short-Term Impact The research focuses on short-term effects, and the long-term sustainability and effectiveness of AR technology in education should be explored in subsequent studies.
4. Technology Accessibility The study assumes equal access to AR technology, which may not be the case in all educational institutions. Socioeconomic factors influencing technology accessibility could impact the results.
5. Subject Variability The diverse nature of subjects may lead to varying impacts of AR technology across different disciplines. Future research could explore subject-specific implications.
6. Teacher Influence The role of the teacher in facilitating AR technology integration is not extensively explored. Further investigation into teacher training and support may provide insights into optimal implementation.
7. Content Quality The study does not delve deeply into the quality of AR content. Future research could assess the impact of content design and alignment with curriculum standards on learning outcomes.
8. Time Frame The study's duration may not capture the full potential of AR's impact. A longer-term investigation could reveal evolving trends and sustained effects.

Recommendations for Future Research

1. Longitudinal Studies Conduct longitudinal studies to explore the long-term effects of AR technology on student engagement and academic performance.
2. Expanded Demographics Include a more diverse sample that encompasses different age groups, educational levels, and socioeconomic backgrounds to enhance the study's external validity.
3. Comparative Subject Analysis Explore the varying impacts of AR technology across different subjects to understand subject-specific dynamics and optimize integration strategies.
4. Teacher Training Programs Investigate the influence of teacher training programs on the successful integration of AR technology, considering the role of educators in maximizing its benefits.
5. Content Quality Assessment Evaluate the quality and relevance of AR content to ensure alignment with curriculum standards and optimize its impact on learning outcomes.
6. Socioeconomic Factors Investigate the influence of socioeconomic factors on access to AR technology, addressing potential disparities and proposing strategies to ensure equitable access.
7. In-Depth Content Analysis Conduct in-depth analyses of specific AR content elements to identify features that contribute most significantly to enhanced student engagement and learning outcomes.
8. Interdisciplinary Approaches Explore interdisciplinary approaches to AR integration, considering collaborative efforts between educators, technologists, and content developers to create holistic educational experiences.
9. Feedback Integration Develop mechanisms for real-time feedback integration into AR experiences, allowing for adaptive learning paths and personalized educational journeys.
10. Holistic Classroom Dynamics Examine the broader impact of AR on overall classroom dynamics, including

collaborative learning, student-teacher interactions, and the development of critical thinking skills.

By addressing these recommendations, future research can contribute to a more comprehensive understanding of the role and potential of Augmented Reality technology in educational settings.

Statements and Declarations

Author's Contributions

Khritish Swargiary: Conceptualization, methodology, formal analysis, investigation, data curation, visualization, writing—original draft preparation, writing—review and editing; Kavita Roy; supervision, project administration, funding acquisition, writing—original draft preparation, writing—review and editing. All authors have read and agreed to the published version of the manuscript OR The author has read and agreed to the published version of the manuscript.

Data Accessibility Statement

- The datasets generated and/or analysed during the current study are available in the [Khritish Swargiary] repository, [RESEARCHGATE.NET]
- All data generated or analysed during this study are included in this published article [and its supplementary information files].

Ethics and Consent

I, KHRITISH SWARGIARY, a Research Assistant, EdTech Research Associations, India hereby declares that the research conducted for the article titled "Augmented Reality (AR) Technology on Student Engagement: An Experimental Research Study" adheres to the ethical guidelines set forth by the EdTech Research Association (ERA). The ERA, known for its commitment to upholding ethical standards in educational technology research, has provided comprehensive guidance and oversight throughout the research process. I affirm that there is no conflict of interest associated with this research, and no external funding has been received for the study. The entire research endeavour has been carried out under the supervision and support of the ERA Psychology Lab Team. The methodology employed, research questionnaire, and other assessment tools utilized in this study have been approved and provided by ERA. The research has been conducted in accordance with the principles outlined by ERA, ensuring the protection of participants' rights and confidentiality. Ethical approval for this research has been granted by the EdTech Research Association under the reference number 01-02/ERA/2022. Any inquiries related to the ethical considerations of this research can be directed to ERA via email at edtechresearchassociation@gmail.com. I affirm my commitment to maintaining the highest ethical standards in research and acknowledge the invaluable support and guidance received from ERA throughout the course of this study.

Author(s) Notes

The calculations, algorithms, and contextual groundwork for this scholarly paper were conducted by EdTech Research Associations, with the collaborative efforts of Kavita Roy and Khritish Swargiary. Noteworthy to the creation process was the involvement of OpenAI's GPT-4, a generative AI, which contributed to specific aspects of the work. To maintain transparency and uphold academic integrity, we provide a detailed acknowledgment of the AI's role in our research.

In accordance with established guidelines, we specify the nature of the AI's contribution:

1. Direct Contribution: Parts of this paper were generated with the assistance of OpenAI's GPT-4. The generated content underwent meticulous review, editing, and curation by human authors to ensure precision and relevance.
2. Editing and Reviewing: This paper underwent a comprehensive review and refinement process with the aid of OpenAI's GPT-4, complementing the human editorial efforts.
3. Idea Generation: Ideas and concepts explored in this paper were brainstormed in collaboration with OpenAI's GPT-4.
4. Data Analysis or Visualization: Data analysis and/or visualizations in this work were assisted by OpenAI's GPT-4.
5. General Assistance: The authors acknowledge the use of OpenAI's GPT-4 in facilitating various stages of writing and ideation for this paper.
6. Code or Algorithms: Algorithms/code presented in this paper were designed with the help of EdTech Research Associations.
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Competing Interests

The authors have no competing interests to declare.

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